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Towards a New Paradigm for Intuitive Theatrical Lighting Control

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A simplified model of a lighting process applied in theatrical productions is one that involves two key players. The first is that of the lighting designer, to produce a set of intentions and plans for the scenes that define the show. The second, the lighting technician, has the job of translating these designs into practice using control equipment, luminaires, and other technical instruments. The lighting design often becomes a 'working document' subject to change and adaptation as the physical reality of the design becomes apparent, and the input of other stakeholders is considered. This process can be a valuable creative tool, and also a difficult technical hurdle to overcome, depending on a varied number of factors. A common frustration with this process is that either the complexity of the task, or difficulty in communication can make it difficult for the final creative vision to be effectively realised. Strains may also arise in the case of small, often touring, theatre companies where the lighting designer and technician may be the same person, and frequently one of the performers as well. Considering the design aspect, there can be challenges in ensuring efficacy of lighting plans between venues in touring productions, with 2D lighting sketches or even 3D computer simulations confined to the paper or screen. From a technical perspective, the role of the lighting technician in theatres and performance situations has included the operation of lighting control equipment during shows. The equipment has evolved over time but has, until recently, been grounded upon the basis of faders and the mixing desk. It is argued that this paradigm has failed to keep pace with the change in other interactive technologies. The on-going research described in this paper explores existing and upcoming technologies in the field, whilst also seeking to understand the roles and communication workflows of those involved in theatrical lighting to find the best areas to seek improvement, adopting principles of user-centred design. The intention of this research is to develop a new paradigm, and manifestation of it, using a control method for lighting or projection that allows a more intuitive form of operation in theatre productions, which will be scalable and flexible.

Lighting design. Pre-visualisation. Collaborative working. User interface design.

1. INTRODUCTION

Theatrical lighting design is a broad discipline, which ranges from working with simple installations to complex applications across a wide range of venues and show types. Lighting designers must consider fundamentals, such as the physical properties of light, and spaces to be lit, in addition to practical constraints, such as luminaire selection, electrical and mechanical connection, and control systems. This process follows consideration of elements such as lighting aesthetic or intent, which is achieved through close collaboration with different individuals and departments before a final design is realised.

In this article, we describe work towards devising technology-assisted, methods of facilitating the lighting design and implementation processes. We review historical and contemporary working practices in the field. Then, present findings from interviews with creative practitioners to achieve a requirements analysis. This leads us to identify a series of thematic areas where our future work will take place.

2. WORKING PRACTICE

2.1 History

Theatrical lighting design is a field enriched by its history, with records of intentional illumination being practiced from some of the earliest recorded performances in Ancient Greece (Arnott 2002). It is possible that during this era some early forms of lighting diffusion or reflection could have been used to enhance the drama of a play (Edison Company 1929). With enclosed spaces later used, there followed a necessity for artificial light, and (Pilbrow 1997) describes the use of torches, fires and oil lamps for theatrical illumination in Roman theatre.
Nagler (1959) describes architects such as Serlio including theatrical lighting devices in their designs for venues throughout the Renaissance. This later spread through Europe and began a formalisation of lighting technology and practice. The presence of lighting practiced in conjunction with drama is found among stage directions of the texts of Marlowe, Jonson and Shakespeare (Hackett 2013).

Izenour (1996) describes gas lighting systems that were developed in the 19th Century in terms of their superior brightness and reliability and also the advent of the 'gas table'. This, as a means of remotely controlling all of the lights in a theatre from a centralised position, was quite sophisticated in comparison to oil systems, and meant that a show could be operated by fewer people, and with less interruption (Jackson 1993).

Electrified lighting was adopted quickly by theatres (Fletcher 1941). This new form of lighting was reliable, consistent and controllable, and led to the development of specialised luminaires and a more scientific and repeatable approach to lighting theatrical productions. Early electric lighting control systems such as dimmer banks operated on a similar principle to gas tables. New control systems were developed with the invention of dimmers such as silicon-controlled resistors, which allowed the dimmers themselves to be remotely controlled (Holloway 2007).

Izenour is credited as the first and most influential inventor of electric lighting control systems for stage (Bringle 2009). His system allowed one or two operators to control a lighting system with up to 10 pre-sets and was small enough to be installed in an auditorium, with a clear view of the stage. This was soon in commercial production and installed in hundreds of theatres, indicating its success (Wilmeth and Miller 1996). A number of competitor systems arose in the decades following, such as those produced by (Strand Electric 1957). These were based on electronic valves, and low voltage-controlled dimmers, with up to 20 presets available.

2.2 Control system development

Lighting control systems are in essence a network of devices that receive control data from a centralised point, such as a computerised lighting console. The devices may include dimmers, special effects or intelligent lights. Computer-controlled systems expand on traditional analogue systems by enabling the control of many more parameters by as little as one operator, or in an entirely automated fashion. The benefits of this approach are reduced infrastructure and manpower cost required to operate a system, in combination with the ability to create and control more complex effects reliably.

An early computerised console was the Electronics Diversified LS8, which was the first computerised memory console to be used on Broadway. (Pilbrow 1997) provides an account from lighting designer Tharon Musser, who describes how the ability to store complex information to computer memory enabled their show to run reliably and repeatedly.

There are many control methods available that allow operators to work in different ways based on their intended application, i.e. pre-set vs tracking modes (Shelley 2013). A lighting operator must familiarise themselves with programming their chosen console often via command line inputs in the correct syntax for each console.

It is not a simple task to acclimatise to a new console, even for an experienced programmer. For example, ETC's Ion console, a popular tracking desk, has over 20 supporting documents, detailing concepts, methodologies and features unique to the Ion (ETC 2018). This depth of functionality applies to the majority of other professional grade consoles available today, which makes changing consoles a non-trivial commitment.

Console purchase costs can be very high and mean that it may be difficult for someone new to the field to gain experience with these consoles. It also represents an expensive single point of failure; while these products are designed to be reliable in their operation, no technology is entirely free of the potential for defects.

There have been affordable solutions developed in the industry, most notably utilising existing personal computers running lighting control software, with an adapter to enable communication with the lighting system. These adapters such as (Enttec UK 2017) USB to DMX adapter, are cheaper, though capable of supporting fewer lighting fixtures than a professional console. An expansion to the capabilities of this form of system represent a possibility for improved accessibility for smaller companies and individuals into this field of work.

The technology underpinning the majority of lighting control for entertainment purposes today is DMX512 (Huntington 2017). This system is capable of supporting 512 lights in a 'universe'. To utilise more than one universe requires support from the control system, and a separate physical cable run (Figure 1), as the end devices are unaware of the universe they occupy. Developments such as DMX512A+RDM have prolonged the life of the DMX standard, but as technology continues to progress, new standards such as (Art-Net 2017) and ACN (PLASA 2015) are being developed to cope with these changes. The major new technologies in current use are still based around end-product compatibility with DMX, although this is also beginning to change.

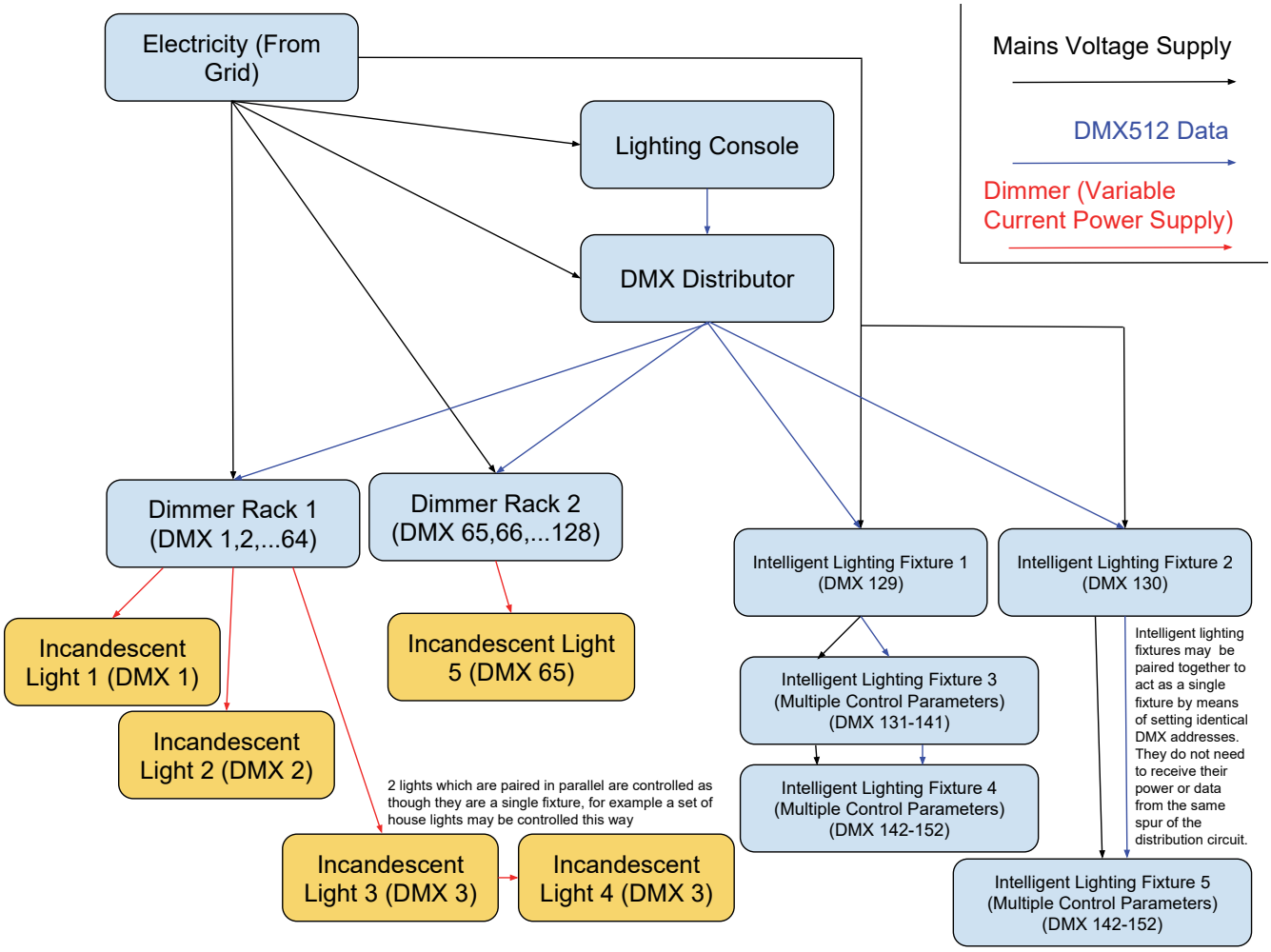

Figure 1: *A typical single universe DMX lighting system topology incorporating both incandescent and intelligent fixtures with a single control point.*

2.3 Current practice

It is the lighting designer's responsibility to create a design that is suitable for the intent of the director, so the first source of information contributing to the lighting design is often the initial production meeting involving the lighting designer and the director. The lighting designer will read the script, or brief, for an understanding of narrative context, location, style, genre expectations and they will ascertain relevant details of venue and budget. They will clarify with the director their intended approach and consider compatibility with practical elements, such as scenery and movements on stage. The designer may question the director on specifics such as establishing mood, atmosphere, foreshadowing and colour themes, in addition to compiling their own portfolio of relevant images and ideas.

Using a combination of these all of these factors, the designer will start to form their ideas, taking into account the practicalities of the building and electrical installation in conjunction with the hardware of other departments involved in the production. They will negotiate ideas with the director and agree upon principles for the design, often based around discussion and rough sketches, then use all of this information to begin to create their lighting plan. This plan must take into account electrical, mechanical and photometric data,

ensuring compatibility with the production venue and budget.

In contemporary productions it is common for a lighting designer to utilise Computer Aided Design (CAD) tools to assist in the drafting of their plan, as this allows for much greater editing flexibility and the programs available have functions to assist with the above considerations.

An example of a popular CAD application used by lighting designers is *Vectorworks* (Vectorworks 2018), which allows a designer to create 2D and 3D plans, and calculate photometric data and mechanical loads, however these operations still require a technical understanding of lighting design, and do not offer solutions for lighting designers without this level of understanding. Simpler programs are available but with fewer features offered to help avoid errors.

(Cuttle 2008) defines mental visualisation as an important creative skill for a lighting designer. With the advent of 3D modelling software, it is possible to manifest this as an animated representation of the design. This can be a useful tool for the designer, to enable them to preview how certain lights will interact on stage, and to verify that their selection of instruments will provide sufficient illumination for a scene. The visualisation can also be an aid to discussions with a director or cast to share the final look of the show, before going into a production space. Using these tools can help designers save money if any errors in the design become apparent through the visualisation, by saving time making corrections in a performance venue.

There are many products available, which offer visualisation capabilities on a PC such as *wysiwyg* (wysiwyg 2018) and *Capture Visualisation* (Capture Visualisation 2017). In addition, some manufacturers offer built in visualisation software in their lighting control consoles, such as on the GrandMA3 console (MA Lighting 2017) to allow pre-programming of a console before accessing a venue. An entire show can be programmed in this way, and the save state of the lighting console used as a 'plug-and-play' show file, pre-programmed and ready to run the show with minimal further programming required at the venue.

While this form of visualisation can be a powerful visual aid, achieving an accurate representation of a venue can take a considerable amount of time, as there are many elements that need to be imported and arranged in a 3D space manually. There are technologies being developed to assist with this step such as venue laser scanning (Preevue 2018), though due to costs and complexity of this currently it is not suitable for all productions. Future developments could help by automating and speeding up aspects of this process.

2.4 Development

Industry-led development in this field is leading to the invention of more sophisticated tools (Laduke 2018) and a greater number of features and options in products. Research in the field includes explorations of alternative paradigms for lighting control, incorporating performer-worn sensors (Saltz 2001), (Francksen et al. 2009), spatial positioning (Hakulinen et al. 2013), natural language (speech) control (Chang & Canny 2009) augmented and virtual reality interfaces for theatre (Cheok et al. 2002), music emotion-based control (Hsiao et al. 2017).

There are further opportunities for creative and technical development of the technologies and processes of theatrical and entertainment lighting, but appropriate direction for effective development could be derived from the practitioners in the field through an examination of their working practices. Through this consultation a targeted system could be identified, which would be placed to provide a useful contribution for those types of practitioners in their work.

3. PRACTITIONER INTERVIEWS

To facilitate insight into the needs of contemporary practitioners, a group of eight (n=8) creative theatrical practitioners were selected to provide their own opinions and information about their creative process of lighting shows, and the effect that this has on their practice. A number of practitioners representing varying roles in the lighting process were identified in order to cover a range of viewpoints present across the discipline. Examples of the roles represented are: Theatrical Director, Theatre in Education Facilitator, Lighting Designer, Visual Programmer and Lighting Operator/Programmer. The interviews were recorded, and a full-transcribed text of each interview was produced. Three quantitative questions and six open-ended questions were asked to each practitioner, where they were invited to talk freely and expand on their answers as they saw fit.

3.1 Analysis

3.1.1 Quantitative analysis
To establish initial, broad opinions from participants, regarding their views on the lighting process and technical aspects, the following quantitative questions and responses were obtained:

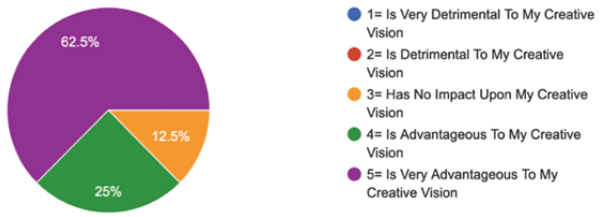

Figure 2: *"I feel that the technical process of lighting shows".*

The responses suggest that the lighting process is valued or felt to have a positive impact on productions, from a range of practitioner viewpoints.

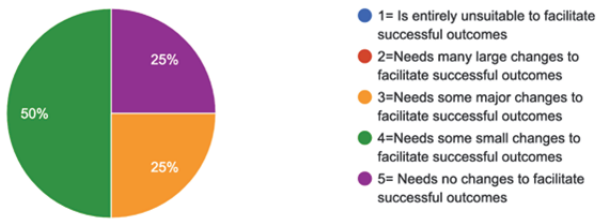

Figure 3: *"I feel that the current lighting process".*

These responses indicated that there is the presence of some frustration with the process, though the nature of these differs depending on both the role and the experience of the practitioner.

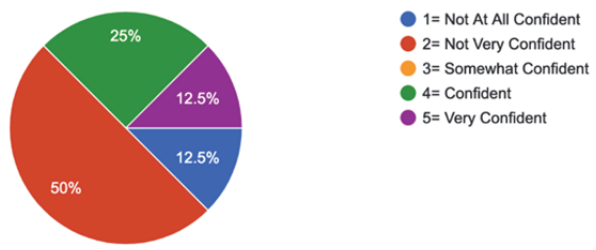

Figure 4: *"The following describes my confidence in my ability in the use of theatrical lighting systems".*

The responses suggest that the lighting process is felt to have a positive impact on productions, from a range of practitioner viewpoints

3.1.2 Qualitative analysis

In order to more accurately reflect the content of the interviews due to their conversational nature, the qualitative questions were analysed and categorised using *NVivo 12* (QSR International 2019), rather than addressing each question individually. This analysis was performed so that if an interviewee were to make a comment, aside, or revisit an area of discussion at a different point than initially anticipated during the interview, this information would still be counted. It also goes some way towards allowing the responses and points raised by the participants to take the lead in the analysis of the interviews, rather than being influenced by the order of questions and potential assumptions of the researcher.

The transcripts were first imported into the software, and a word query was carried out to find any patterns or recurring themes between interviews as an initial 'broad strokes' analysis. Discounting generic terms such as 'things' or 'get' and looking for related terms, a number of initial terms were identified. From this list, words such as show, design, vision, confident, creative, successful, changes, practitioner, systems and others were identified, and gave a starting point for themes.

Figure 5: *A word cloud view of the transcribed interview texts.*

From this broad analysis, some of the words were then combined or discounted altogether, such as 'lights', due to this being the main topic of discussion, and combination of terms such as 'shows' and 'productions' as synonyms, which would not be recognised by this form of analysis. After this step a number of prevalent themes were identified, and the interviews were marked up with each of these terms or themes using the NVivo nodes classification tool.

This process allowed the identified themes and recurring topics to be classified, and further codes were identified during this process. Once this process was complete the resulting nodes were explored and combined and categorised as appropriate into broad themes.

The themes identified were:

1) The quantitative questions and related comments;
2) Descriptions of the working processes of the interviewees;
3) The problems encountered, identified and described;
4) Possible solutions proffered by the interviewees.

The themes were categorised where relevant and organised as shown in (Table 1).

Table 1: *Response themes*

Theme	*Explanation & Quote*
1.Quantitative Questions	***Comments related to the multiple-choice questions:***
Confidence	"At which point I acknowledge my technical ineptness at any questions of technicality, so I rely on people who know a lot more about it than I do to come up with some possibilities"
Creative Vision	"It's not always advantageous to the creative vision, it depends on the shows, the facilities, the people that you're working with."
Outcomes	"I think I'm surprised by what we can achieve and by how much good lighting can elevate the production"
2.Working Process	**A number of practitioners discussed their working processes:**
Collaboration	"I think the fact that it is a collaborative process, where you bring people together from different disciplines, if everyone's working at their best – that's what makes shows more than the sum of their parts"
Design Process	"The first part of the process is defining the envelope you're working within or determining the size of the box."
3.Problems	**The different problems encountered were categorised:**
Cost	*"A lot of what you start with in terms of designing is basically a bit of value engineering really. You're going through and figuring out what can we do, what's possible."*
Technical	*"I know naff all about lighting systems, sound systems, stage management practices, so I give people the space within the process to do their work."*
Time	*"We don't often have enough time to really experiment (ever) when we're hiring out a theatre, the margins of error are too tight"*
Venue	*"Sometimes there can be issues with building infrastructure that are insurmountable."*
Equipment	*"I think one of the big things is not knowing everything I can do with a particular light for example, or even not being 100% sure about what a light is or even where it is sometimes"*
4.Solutions	Finally, potential areas or suggestions for solutions were identified:
Library/Scenes	*"Having automatic settings that you can then play around with i.e. Summer evening, winter evening. Having these options and modifiers such as mood and time of day – can you represent tension?"*
UI	*"Something changing on the front-end interface. In some cases, literally numbers are representing an abstract concept such as light, where they don't capture any meaningful relationship with the outcome."*
Visualisation	*"I think that the sooner you can get to that state where you're discussing a pictorial representation of what something might look like, rather than just using language to describe it the better. So, something visual, some approximation of what the effect might be, or what the state might look like, could reduce the amount of ambiguity."*

In order to better visualise the distribution and frequency of answers related to thematic nodes a matrix was produced which referenced the interviews against the number of times they referred to each identified node. Using a red-yellow-green shading pattern with the highest number representing red and the lowest representing green it became more intuitive to identify 'hot-spots' of nodes which were referred to by a number of practitioners.

In analysing the node matrix in this way, it is possible to get a sense of which themes broadly recurred across a number of practitioners, which is information not readily given by the numerical views above. This is useful as in the example of interview 6; the interviewee was very detailed and verbose in his responses and had more than twice the coded references of any other interview after analysis. This could have influenced the results to favour the responses of interview 6, but the shaded matrix node query helps to mitigate this issue somewhat, by enabling a glance at the vertical columns representing the identified codes, allowing a view of the most common terms across all participants.

3.2 Discussion

Several themes emerged from these interviews, which give impetus and direction for further exploration in developing a system to improve the process of realising lighting design on stage.

The main themes that emerged were led by the practitioners in their responses to generalised questions about the process, suggesting that there is validity in the origin of the responses given, rather than being led by the research questions. The emerging topics from these interviews are:

- Facilitation of effective collaboration and communication amongst stakeholders
- Time management strategies

The technological development to address these could take its form in areas identified by the interviewees such as:

- User Interface development
- A library of options for the user
- Pre-visualisation technology

Factors such as the extant design process and elements such as cost and interoperability with existing systems described above would need to underpin these areas of exploration. It is likely that these topics will see further refinement and develop into a smaller number of areas, as there is some overlap, with the topics having an impact on one another. From this research section it is felt that further involvement with industry practitioners would be of benefit in determining the ultimate success of any solutions developed at this stage.

4. CONCLUSIONS AND FUTURE WORK

Developing a number of focussed models based around the impetus provided by these practitioner interviews is the next planned step for this research. The design of a study to accompany these models and determine their efficacy in facilitating more intuitive workflows and effective communication could be the initial method of determining success.

4.1 Contextual UI

A system that allows users to input variables, such as lighting equipment available, venue dimensions, and hanging points for fixtures and then intelligently offered suggestions on placement and focus could offer a meaningful improvement to the tools available to designers, while also creating a more accessible tool for those with less technical training. If the tool was more responsible for the technical choice of placement for units this could allow an operator to focus further on the creative possibilities, rather than being burdened by the operational difficulties. The end user could be presented with their venue, including instruments, set up at installation, showing their instruments and options in the context of what controls are available to them, based on the options selected.

4.2 'Friendly' UI

A system that takes the current process as its underpinning operating principles, with any technical information, and especially numerically represented data, being presented in a more simple and friendly way. An interesting parallel in audio interface research by (Mycroft et al. 2018) could represent one area for exploration.

4.3 Spatial positioning

In software applications it is possible to select a number of virtual lighting instruments, place them inside a space, and to point them at a target, or distribute their beams evenly over a 2D plane such as a representation of a stage. This is not currently a feature available on theatrical lighting consoles, as the position data for lighting fixtures is not available. Were this incorporated, a new paradigm could be developed which allowed operators a simple button press operation to focus many lights on a given area, reducing end user complexity.

4.4 Emulated (projected) lighting positions

A lighting design is built-up by a plurality of lighting instruments in different spatial positions performing different aesthetic functions when converging on their target. A basic 3-point lighting system with key, fill and back lights requires three lights to be set up in predetermined locations to enable the desired function. Theatrical lighting deals with many times this number of positions, impacting on time, flexibility, and even the safety of show production. While many lighting angles are needed to produce effects such as side-fill, the results are often viewed from a very narrow range of angles. In a similar way to efficient computer rendering only representing what is seen on screen, the differing lighting positions could be emulated by projecting a complex lighting overlay onto a stage which, when viewed from the correct angle, would give the impression of multiple lighting positions.

4.5 – AR/VR visualisation overlay

Directly intervening in the collaboration process and offering a tool for directors and designers which would allow an augmented reality picture to be overlaid which can display and modify lighting conditions and facilitate creative discussions. This would likely be app based, for example using the camera built into a tablet or mobile phone, to allow an operator to preview a stage position, with a selected lighting state overlaid.

4.6 Library

Presenting end users with a range of options to select using natural language, and potentially speech recognition, could be a more intuitive means to control lighting systems. The lighting states would need to be suitable for their intended application for theatre, and respond appropriately to adjustment commands, such as 'Down stage left a little brighter'. This could allow an operator to ask for scenes such as 'Night-time' or 'Restaurant' and be suitable for education, rehearsals, or the initial outlining scenes within a performance space.

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